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Best Practice Guideline – Storage and Handling of torrefied biomass

Prepared by:
Danish Technological Institute
Teknologiparken
Kongsvang Allé 29
8000 Aarhus C
Biomass and Biorefinery

Author:
Wolfgang Stelte

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1. Scope

The intention of this guideline is to provide recommendations for the handling and storage of torrefied biomass fuels in a responsible and safe way, minimizing risks for health and safety. The guideline is addressing producers, transporters and end-users of torrefied biomass fuels.

Most experience regarding the handling and storage of torrefied biomass is based on pilot- and/or small to medium scale batches of torrefied biomass. At the time writing these guidelines, there is only limited data available on the handling and storage of large bulk volumes of torrefied biomass, i.e. oversea bulk transport on fright ships or production scale storage of torrefied biomass on a coal yard.

2. Introduction to torrefaction technology and energy carriers made from torrefied biomas

Torrefaction is a thermal pre-treatment process in which the biomass is heated up to 200-300°C in the absence of oxygen (usually under nitrogen atmosphere). The resulting product has a lower oxygen content, higher calorific value, low moisture content, and less hydrophilic compared to the untreated biomass. Furthermore, the fibrous and tenacious nature of the biomass is reduced, resulting in a brittle material that can easily be comminuted into smaller particles (van der Stelt et al. 2011).

According to van der Stelt (2011) the torrefaction process can be subdivided into five stages:

1. Initial heating: The temperature is increased until moisture starts to evaporate and drying of the biomass begins.
2. Pre-drying: At 100 °C the free water is evaporated from the biomass at a constant temperature.
3. Post-drying and intermediate heating: Further heating of the biomass to about 200 °C
4. Torrefaction: During this stage, the actual torrefaction process takes place. The temperature is further increased to about 270 to 310 °C and the biopolymers especially hemicelluloses are undergoing condensation and dehydration reactions resulting in the release of gas (torrefaction gas) and torrefied biomass.
5. Solids cooling: Cooling of biomass below 200 °C

The different phases of torrefaction processes and their effect on the biomass are illustrated in Figure 1.

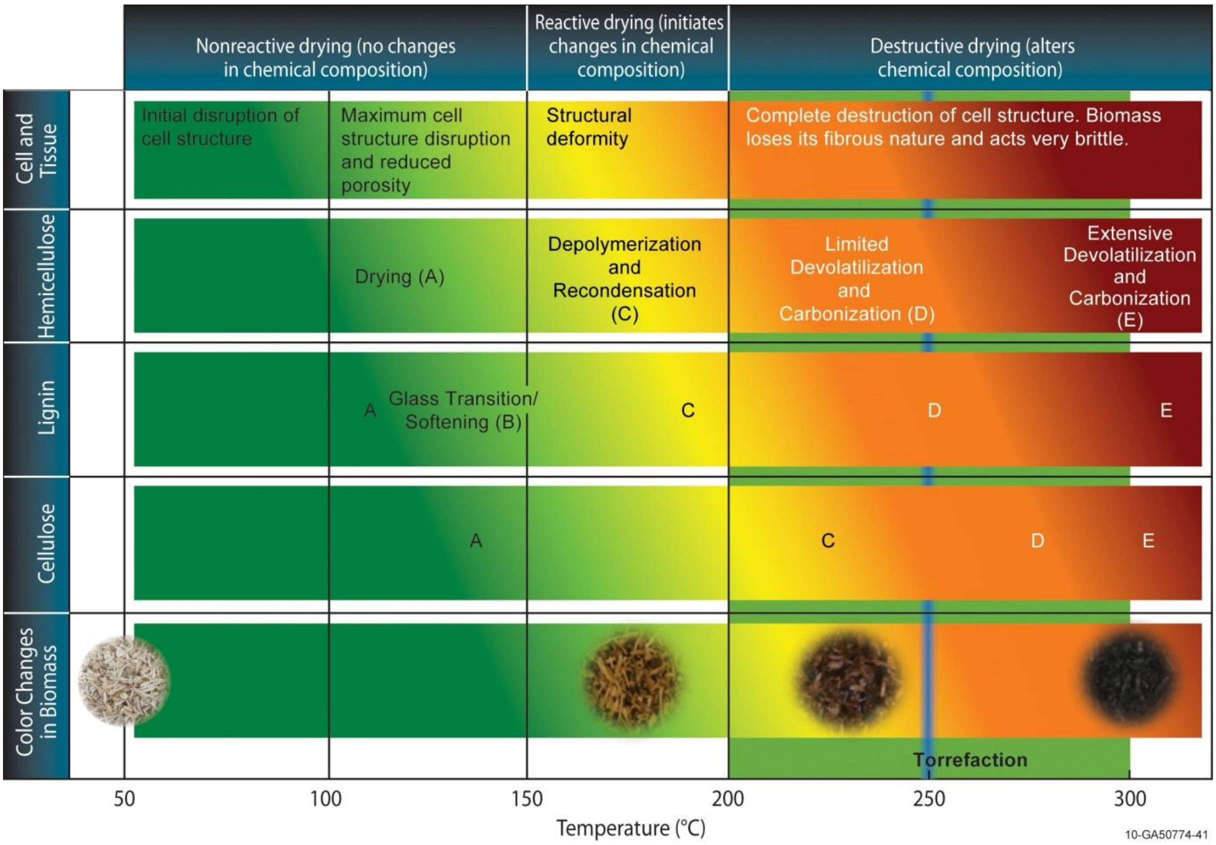


Fig. 1. Effect of torrefaction of biomass (Tumuluru et al. 2011)

During torrefaction, the biomass is partly decomposed, and low molecular organic volatile compounds and water evaporate from the biomass (Prins et al. 2006). This results in a decrease of mass, while the initial energy content is only reduced slightly. During the torrefaction process, biomass typically loses 20–30% of its mass, while only 10% of the energy content in the biomass is lost. The volatile compounds removed during torrefaction can be combusted and utilized for running the torrefaction process. The volatiles can be subdivided into condensable and non-condensable compounds. Condensable compounds are mainly water and organic acids, while non-condensables consist mainly of carbon monoxide and carbon dioxide (Prins et al. 2006).

Torrefaction alters the biomass hydrophilic properties to more hydrophobic ones, which allows outside storage and exposure to rain, snow and moist air for a reasonable storage time (Carbo et al. 2015). The advanced storage properties go hand-in-hand with a greater resistance against biological degradation, self-ignition and physical decomposition in general (Willen et al. 2013).

Torrefaction has been studied extensively at laboratory and pilot scale with respect to different feedstocks and process parameters (van der Stelt et al., 2011; Chen et al., 2015; Ciolkosz et al., 2012; Tumuluru et al. 2011; Willen et al. 2013).

Torrefied biomass is not suitable for transport directly after the torrefaction process. The material is too brittle and too light in weight to be transported or stored cost efficiently (Wild et al. 2016). Torrefied biomass is therefore usually compacted, into briquettes or pellets using conventional densification equipment, to further increase the density of the material.

3. Description of storage and handling

The logistics chain from the torrefaction plant to the consumer's combustion chamber can be broken down to the following elements (Wild et al. 2016):

- Loading to truck/train/barge
- Secondary transport to ocean vessel
- Loading the vessel
- Shipping
- Unloading/reloading to truck/train/barge
- Tertiary transport
- Unloading
- Storage
- Internal transport and handling
- Grinding

Torrefied densified biomass can use existing wood pellet chains. This is valid for the storage and all auxiliary equipment in loading and unloading storage and transportation. Generally, the supply chain elements can be separated into handling and storage operations.

3.1 Handling

Production plant

Torrefied biomass leaving the torrefaction process is a hot and reactive material that needs to be cooled down to prevent immediate reaction with the oxygen in the atmosphere. This is done by cooling conveyers and sometimes quenching of the material with water sprayers. The torrefaction process takes place in an oxygen depleted; inert atmosphere and newly torrefied material can therefore be quite reactive when exposed to air. The reactivity of torrefied material depends on a number of factors such as torrefaction temperature, retention time, reactor type and wood species. Torrefaction operators are aiming for less reactive products to reduce the risk of self-heating and fires in their production lines and storage facilities.

The torrefied material is furthermore too brittle and too light in weight to be transported or stored cost efficiently. Torrefied biomass is therefore usually pressed into pellets or briquettes shortly after production, which increases the energy density and reduces dust formation and reactivity of the torrefied material.

Loading and transport

At the present time there is limited practical experience available on torrefied product as there has been only a few long-haul bulk shipments of torrefied product. However, trucking and transportation in containers has been observed in larger numbers (Wild et al. 2016).

Already established supply chains and handling procedures from the wood pellets industry can be directly applied to pellets made from torrefied biomass.

Loading and transport of torrefied fuels is similar as for wood fuels. Loading should be conducted with a minimum of wear and damage to the solid fuel - Especially pellets are sensitive to physical wear. Dust and fire-prevention and important aspects of every transfer system to be used for torrefied biomass.

Transport of torrefied biomass can be by ship, train or truck between producer, supplier, retailer and end-user at different size levels. Figure 2 shows examples of loading at producer sites.

Torrefied biomass fuels are relatively new to the market and registration and classification procedures at the national/international authorities as well as insurance companies are ongoing.

Material datasheets for torrefied biomass are under development and REACH registration is under discussion (see page 15 for more information).

Figure 2. Loading of torrefied wood pellets from NEW BIOMASS ENERGY (Wild, 2014)

Unloading and internal handling

During long distance transport in closed vessels, it is important to ensure good ventilation before entering the vessels storage room. Oxygen depletion, as well as possible off-gassing from biomass, are a potential health risk for working personal entering the vessel.

Unloading and handling processes should be designed to avoid the formation of dust and fines, and reduce the risk for ignition and dust explosions. Mechanical impact and wear such as dropping the material onto a hard surface or conveying and pumping at too high rates should be avoided. Precautions measures should focus on avoiding over-heated or burning loads, spark detection and fire extinction system.

Conveying

Conveying of torrefied biomass takes place at the producer site, at the supplier, retailer and end-user. In case of pellets, pneumatic pumping may be used instead of belt conveyors.

Conveying of torrefied biomass fuels should be conducted at a minimum wear to avoid damage i.e. breakage and abrasion. When designing the conveyor system, high drops and many crossings should be avoided to minimize the mechanical stress. Torrefied biomass pellets are very sensitive to mechanical loads due to the high brittleness of torrefied materials.

3.2 Storage

Torrefied biomass pellets, briquettes and chips are new types of fuel and numerous storage tests have been made during the past decade, mainly on torrefied pellets.

Indoor storage

Indoor storage of torrefied biomass pellets is similar as for conventional wood pellets either in a frame- or silo storage and the general storage guidelines for handling of wood pellets can be applied (Stelte, 2014)

Indoor storage prevents the torrefied pellets from getting wet and preserves the pellet quality at a high level over a long period of time. The storage room should be monitored well for CO concentrations as well as temperature inside the bulk. Self heating may occur also in torrefied biomass, especially when freshly produced. The storage room should be ventilated well before entering to prevent oxygen depletion and high CO concentrations.

There are some general recommendations to avoid self-heating and self-ignition of indoor biomass storage compartments, that are valid for conventional wood pellets and are also applicable for torrefied biomass storage. According to Obernberger and Thek they can be summarized as follows:

- Avoid storage and transport of large volumes if the fuel's tendency for self-heating is
- unknown
- Be conscious of the risk of self-heating and spontaneous ignition in large storage
- volumes
- Avoid mixing of different types of biomass fuels in one storage
- Avoid mixing of biomass fuels with different moisture content
- Avoid large parts of fines in the fuel bulk
- Measure and monitor the distribution temperature and gas composition within the
- stored material
- Prepare (large) silos for gas injection at the bottom of the silo in case a fir should occur
- Pellet storage units must be equipped with size dependent, appropriate means of ventilation control to remove carbon monoxide and carbon dioxide

Outdoor storage

The outside storage of torrefied biomass pellets and chips has been subject in numerous studies (Carbo et al., 2015; Kymäläinen, 2015; Järvinen, 2015) . Although torrefied biomass is more moisture resistant and less susceptible for microbiological degradation than woodpellets, there are limitations for outside storage.

Those studies have concluded that torrefied biomass can be stored outside for a limited period of time. How long the pellets retain their initial quality and how fast they deteriorate depends to large extend on their the initial quality, stack size and shape, and the climatic conditions. High quality pellets (sealed, glassy pellet surface) can withstand moisture better than pellets of low quality (cracked surface) where water can penetrate inside the pellet body more easily.

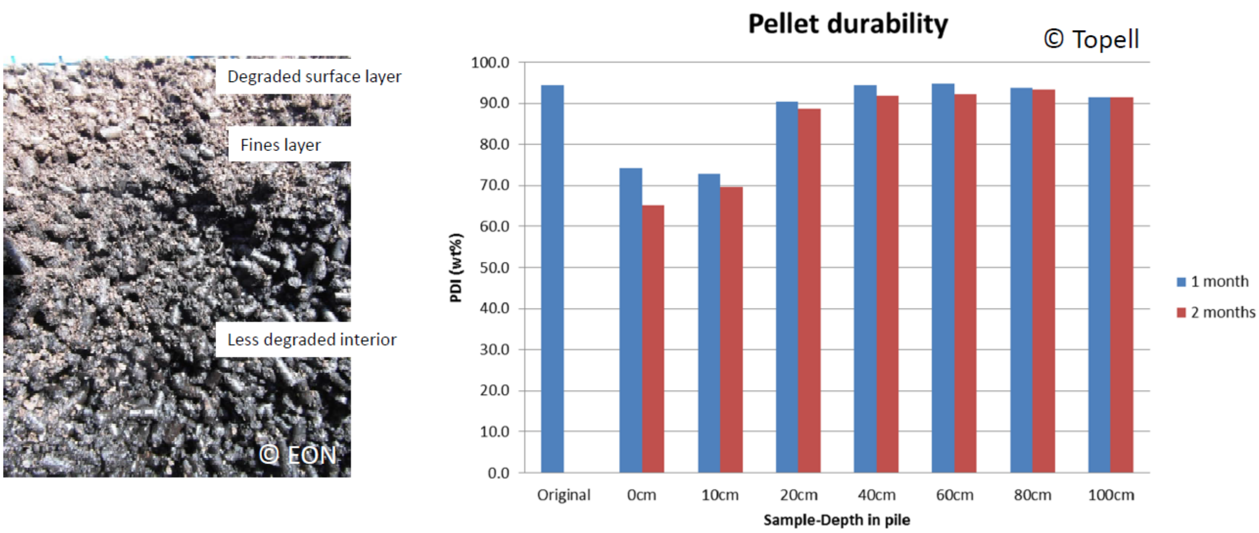
Outside storage tests with torrefied pellets were made in heaps and monitored for their moisture content, and mechanical durability over time. A test set-up for out-door storage tests made by major European power providers within the European research project SECTOR is shown in Figure 3 (Carbo et al., 2015)

a) b)

Figure 3. Outside storage tests made by a) EoN and b) Vattenfall in context of the European Torrefaction Research Project - SECTOR (Carbo, 2015)

The pellets on the surface of the heap are most exposed to rain, resulting in their disintegration and fines formation. It was found that those fine accumulate at about 5-15 cm below the surface of the pile forming some kind of crust layer (Figure 4a), that is shielding the pellets below from moisture penetration into the pellet pile. Thus, the inside of the pile remain dry and the pellet durability remains to be high.

Figure 4 shows the pellet durability in an outside pile after 1 and 2 month of storage time for samples taken at different distance inside the pellet pile. The durability inside the pile remains at a high level while the pellets at the surface a degrading in durability.



a) b)

Figure 4: a) Image of a pile surface indicating a layer of surface and fines that prevent moisture from penetrating into the pile b) Pellet durability for torrefied pellets inside an outdoor pile after one and two month outdoor storage (Carbo et al., 2015).

Industrial end-users such as power plants will crush and mill the torrefied pellets after storage and thus a minor degradation in pellet quality may not be a problem for them at all. Producers, suppliers and retailers of torrefied pellets have to meet the end-users quality demands which need to be taken into account when considering an outside pellet storage.

Fungal degradation has been observed in some long term outside storage trials, deteriorating the torrefied biomass. Only few studies have been made on fungal degradation. Reducing the storage time and moisture penetration into the pile will also reduce the risk of fungal degradation. Kymäläinen (2015) has made a detailed study about moisture resistance and fungal degradation of torrefied biomass.

3.3 Supply chain Comparison between wood chips, pellets and torrefied biomass carriers

A recent report has reviewed and compared the supply chains for wood chips, pellets and torrefied biomass carriers (Wild et al. 2016)

	WOOD CHIPS	**WOOD PELLETS or BRIQUETTES**	**TORREFIED WOOD PELLETS/BRIQUETTES**
DOCUMENTS			
Certificate of Origin	yes	yes	yes
Subject to Phytosanitary Regulation	Certificate Required	no	no
IMO 4.1 flammability		no	no
IMO 4.2 self heating			no
IMSBC	Yes p 287f	Yes p 289f	MSC 92/26/Add.1 p37
HS code			
Customs code	High quality chips44012100 soft wood, 44012200 others	4401 3020,440131..	in process, today charcoal code but changes expected
	lower quality chips and forest industry by-products (bark) 44013080		after ISO standard is completed
REACH	Excepted	Excepted	unclear, clarification with ECHA in progress
ISO standard	17225-4	17225-2	17225-8 in progress
EN Standard	14961-4	14961-2	
EVALUATION			
Quality Determination	Moisture	fulfilling standard and class	fulfilling standard and class
	Size	certification	NCV
	bark content	NCV	fines
	NCV	fines	ash&ashmelting
			grindability
HANDLING			
Hazards	may be subject to oxidation leading to CO	may be subject to oxidation leading to CO	may be subject to oxidation leading to CO
		Swelling if exposed to moisture	
		dusting	dusting
Fire risk	low>15% moisture		MHB
STORAGE AND SEGREGATION			Segregation as for class 4.1 materials
Loading/Handling	free trimming	free trimming	free trimming
weather precautions/water sensitive	no	yes, as dry as practicable	cargo shall be kept as dry as practicable
open storage	yes	no	short term yes, long term no
closed storage needed	no	yes	no/yes
offgassing observation needed	in closed storage yes	yes	no
Ventilation requirements	recommended	recommended before entry	testing before entry, vent if necessary
storage factor in vessel ft3/mt	85-230	53-59	49-54
kg/m3	150-400	600-660	650-800
IMSBC group	B	B	B

4. Problems and Risks

Problems and risks for handling torrefied biomass fuels are mostly connected to physical damage and loss of quality along the supply chain, resulting in fines and dust formation. Other known issues are self-heating and spontaneous ignition of torrefied biomass, that sometime occur in freshly torrefied materials and due to improper production processes and subsequent handling.

4.1 Physical damage and loss of quality

Torrefied biomass pellets are dryer and more brittle than conventional wood pellets, and thus more sensitive towards mechanical impacts, i.e. dropping from a conveyor belt or vacuum pumping. High shear forces should be avoided or at least limited to a minimum, during the transport/conveying operations of pellets made from torrefied biomass. The measured durability of torrefied biomass pellets is comparable with conventional wood pellets. Physical damage through improper handling during loading, conveying and transport may result in the formation of fines and dust that increase the risk for dust explosions. Dust emissions are also problematic from a health perspective, and workers should not be exposed to this dust, and be equipped with suitable protection, such as protection glasses, dust masks or portable respirators equipped with particle filters.

4.2 Dust, self-heating and spontaneous ignition

As with most dusts generated during biomass handling and processing steps, dust and dust layers of torrefied biomass are a potential source for dust explosion and self ignition. From a safety perspective dust from torrefied biomass does not differ significantly from wood dust, but is clearly more reactive than coal dust as shown in Table 1. Dust from torrefied biomass can be classified as a class St1 dust, as most fuel dusts.

	Explosion pressure Pmax (bar g)	Rate of pressure rise Kmax (m*bar/s)	Limiting Oxygen Concentration LOC (%)
Torrefied wood dust	9.0	150	11
Wood dust	9.1-10.0	57-100	10-12
Peat dust	9.1-11.9	120-157	13.5
Lignite dust	9.4-11.0	90-176	13-15
Coal dust	8.9-10.0	37-86	14

Explosion class	Kmax value (m*bar/s)	
St0	0	non-explosive
St1	≤ 200	weak, normal
St2	201–300	strong
St3	> 300	violent

Source: Wood torrefaction – pilot tests and utilisation prospects; Carl Wilén, Perttu Jukola, Timo Järvinen, Kai Sipilä, Fred Verhoeff & Jaap Kiel. Espoo 2013. VTT Technology 122.

Due to the small particle size and low moisture content torrefied dusts may have an increased dust explosion risk compared to conventional dusts. The elimination of dust formation and ignition sources is therefore critical during the entire production and supply chain of torrefied biomass.

Self-heating and spontaneous ignition of torrefied biomass is difficult to predict, partly because of the long time span these reactions require. Biomass reactivity depends on numerous parameters such as moisture content, raw material type, temperature, particle size and its reactivity typically decreases with storage time after the torrefaction process. Freshly torrefied biomass is usually most reactive, especially when hot and when exposed to oxygen. Torrefaction occurs in an oxygen-depleted environment and torrefied biomass leaving the torrefaction reactor may react with oxygen under generation of heat.

Dust explosions can occur as a separate event or as a secondary consequence of a fire or fire-gas explosion. ATEX regulations should be followed strictly and correct zone classification for production, handling and storage processes should be made to define and mark risk areas.

4.3 External ignition sources

External ignition sources are heat sources from for example conveyor friction, feeders, electrical motors, lamps and back fire and sparks from near boilers. Sparks from static electricity or from rocky and metallic materials in the fuel handling system, may also act as an external ignition sources. Spark detectors in critical processing parts i.e. milling systems and fire/heat monitoring systems along the conveyors and inside the storage compartments may reduce the risk.

4.4 Health risks

Gas emissions and oxygen depletion

The emission of toxic gases (mainly carbon monoxide) from conventional wood pellet storages is a well documented phenomenon.

There are few studies made on emissions from torrefied biomass storages yet. Therefor the same safety measures as for conventional wood pellet storages should be applied. Torrefied biomass (especially when fresh) tends to react with oxygen, which can deplete the oxygen content in a storage room.

Mould and dust

The dusts from torrefied biomass is a potential health risk when inhaled by workers. Dust atmospheres should be avoided and respirators, masks should be used when entering a dust loaded atmosphere. Fungi can grow on moist torrefied materials and may result in the formation of bio-aerosols in subsequent handling steps. The generated aerosols may contain spores and fungal components that are potentially harmful when inhaled.

5. Prevention of problems and risks

5.1 Improvement of storage

Due to seasonal fluctuations with periods of high heat and power demand (winter) and periods with moderate or low demand (summer months) pellet producers, intermediate traders and end-users need storage capacity matching their needs. Pellets made from torrefied biomass can be stored inside or outside, covered or uncovered, depending on climate, storage time and quality requirement.

Indoor or covered storage are recommended for long-term storage at the producers or traders site, to maintain a high quality of the product. Uncovered storage, exposed to moisture and precipitation is possible for a limited period of time and depending on the climatic conditions and quality requirements of the end-user.

Indoor storage

Indoor storage rooms should be protective against moisture exposure i.e. precipitation and other sources. Torrefied dust is fine and has electrostatic properties, sticking to walls and other surfaces.

Silo storage is the most common way of storing pellets at power plants, pellet producers and harbors. Silos are consuming less space as storage halls and can be filled and emptied easily using screw conveyors. The size of the silo depends on its function. Large silos with several thousand cubic meter volumes are common as intermediate storage at harbors or at large scale pellet consumers. From there pellets are distributed to transport vessels, or feeding bins.

Flat storage building i.e. A-frames, are used for bulk storage of pellets and are used for large storage of pellets in a range from 15.000 to 100.000 m^3. They are used at the pellet producer's site, for intermediate storage at harbors and at the end users i.e. power plant site. Pellets are conveyed into the building and dropped down onto the floor forming a pile and/or moved by front loaders onto a pile. Emptying of this kind of storage is made by front loaders either into a feed system for a boiler (power plant site) or onto trucks, vessels or rail cars for further transportation. Especially moving pellets with a front loader bears the risk for fines and dust formation and as such a risk for health and dust explosion.

Temperature in an indoor pellet storage should be monitored continuously by sensors embedded in the stored product. An alternative and/or addition to direct temperature measurement can be equipment sensing carbon monoxide, hydrocarbons, radiated heat and smoke as precursors for overheating. Even at low temperatures low temperature oxidation of pellets will result I the formation of carbon dioxide, carbon monoxide, aldehydes and methane and these gasses will deplete the oxygen in the silo. One option to cool and ventilate a pellet silo at the same time, is to ventilate a storage silo whenever the ambient outside temperature is lower than the temperature inside the storage. In case of too high temperatures (> 80 °C) emergency procedures should be in place. This could be emergency discharge of the pellets by relocating them into a different storage or outside and thus breaking up the hotspots and cool the pellet bulk. In general, the temperature in a pellet silo should be kept below 45 °C.

Outdoor storage

Torrefied biomass pellets vary in their quality and moisture resistance. High quality pellets are generally more moisture resistant than low quality pellets. The pellet surface (smooth vs. crackled) is a good indicator.

Torrefied biomass pellets can be stored outside without cover for a limited period of time. An appropriate logistic system at the storage site (first in-first out) and reducing the amount and storage time to a minimum should be established to prevent degradation of the torrefied biomass.

A roof or plastic cover should be considered to increase outside storage time and may even be sufficient for long-term storage of pellets made from torrefied biomass.

5.2 Prevention of fire and explosion

Prevention of Self heating and self-ignition

The risk for self-heating of torrefied biomass increases with the amount of biomass (stored volume) and the ambient temperature. In addition, the reactivity of the material plays a big role (i.e. freshly torrefied material is more reactive as "old" material). Reactivity may be determined by determination of oxygen consumption in a defined mass of torrefied biomass such as the "oxipress-method" (Emhofer, 2012).

General measure to reduce the self-heating, self-ignition risk are:

- Fuels of different origin and quality should not be mixed (especially when the reactivity is unknown)
- Store preferably in small piles for a short time
- Avoid metal objects in the pile
- Monitor temperature and CO concentration in the storage
- Temperature sensors in the pile
- Fire extinguishing systems and emergency plans are in place

Reduction of External ignition sources

Identify and eliminate potential external ignition sources

Important sources are:

- Hot points or fir pockets in fuel or raw material delivery
- Receiving operations (screening, crushing, conveying) in combination with impurities in the material (metal, rock)
- Hot surfaces in the process i.e. electrical motors, bearings, lamps

Fire extinguishing

Generally, measures for fire extinguishing are different for indoor and outdoor storage.

Outdoor

- Locate hot-spots and dig out and remove warm/active material from the stack

- Spread out the material at a safe place and let it cool off
- Use water spray/jets to cool/extinguish pyrolysing material during the extinguishing operation. Water shall also be used to control any open fire. Water additives, e.g. fire fighting foams and wetting agents might improve the extinguishing efficiency.

Indoor

- Locate hot-spots and dig out and remove warm/active material from the heap.
- Spread out the material at a safe place and let it cool off.
- Use water spray/jets to cool/extinguish pyrolysing material during the extinguishing operation. Water shall also be used to control any open fire. Water additives, e.g. fire fighting foams and wetting agents might improve the extinguishing efficiency.

Silos

Fire extinguishing in silos is very difficult. In an early stage the emptying of the silo migt be an option but outside oxygen may trigger the fire. Filling the silo with an inert gas i.e. Nitrogen or Carbon dioxide are options but require skilled personal and is expensive.

- Water might be used, since torrefied pellets do not swell up as conventional wood pellets

A detailed description of firefighting measures in pellet silos has been published by the Swedish Civil Contingencies Agency (Persson, 2013).

Prevention of explosion

Following of ATEX regulations and zone classification by an expert help to identify risks and to prevent dust explosions. Dust from torrefied biomass is drier and particles are smaller which makes it more reactive and susceptible to dust explosions.

5.3 Prevention of health risks

Dealing with gas emissions and oxygen depletion

Torrefied biomass might deplete the oxygen concentration in a closed storage compartment due to oxidizing reactions. At the same time Carbon monoxide (CO) might be released into the surrounding atmosphere. It is therefore recommended to follow the guidelines for storage and handling of wood pellets that suggest good ventilation of closed storage compartments before entering.

Doors to storage compartments should be locked and market with warning signs. The access to storage rooms should be restricted to rained personal only.

Dealing with dust

Dust is a common problem when dealing with biomass handling and processing. Dust masks and respirators as well as protection wear will limit the dust exposure of working personal. Dust concentration are usually highest during and directly after handling operations, which should be taken into account when planning to enter a dust zone.

Dust is not only a health hazard but also a risk factor for dust explosion and ignition. The high surface area of dust and its dispersion in the air increases the reactivity of the biomass. ATEX regulations should be applied and hazard zones should be classified accordingly. Dust can cover hot surfaces i.e. lamps, engines and result in a build up of heat and ignition of the biomass. Avoiding dust and regular cleaning as well limiting electric installations to a minimum will decrease the risk of dust explosion, ignition significantly.

5.4 Safety classification and standardization

MSDS

Material safety data sheets (MSDS) include information about the properties of the substance (or mixture), its hazards and instructions for handling, disposal and transport and also first-aid, fire-fighting and exposure control measures.

A template for a MSDS for torrefied biomass has been developed within the European Research project SECTOR (Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction), can be accessed om the project website:

https://sector-project.eu/fileadmin/downloads/deliverables/SECTOR_D8.6.__DBFZ__final.pdf

REACH

Whether a registration under REACH for torrefied material is required has not been decided at the present time. It is still under discussion whether the torrefaction process should be classified as a "chemical treatment" process or not. The biomass feedstock used for torrefaction do not require REACH registration and neither do related products such as coal

Customs declaration

Currently torrefied biomass is classified under the charcoal customs code 44029000. At the time authorities did this classification no standard on torrefied biomass was available and information (Wild et al. 2016)

ISO standardization

It is expected that an ISO Technical Specification or a full ISO standard covering thermally treated, solid biofuels, will be released later in 2016 under ISO 17225-8 (Wild et al. 2016).

IMSBC

The main legislation governing safe carriage of solid bulk cargoes is the International Maritime Solid Bulk Cargoes (IMSBC) Code. According to Wild et al. (2016) torrefied wood (not torrefied agro products) is within the IMSBC allowed to be shipped in bulk provided the vessels are CO_2 fitted- equipped with fixed gas fire extinguishing systems (CO_2).

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